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Injuries in the vulnerable road user fatalities; a study from Sri Lanka

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ABSTRACT

Vulnerable Road Users defined as people at risk in traffic due to absence of an outside protective shield to absorb energy during a collision are mainly pedestrians, bicycle riders and motor cyclists. In low income countries, deaths of VRUs outnumber vehicular drivers and occupants. A forensic pathologist not only reports the cause of death but also forms opinions on type of road user. We attempted to find whether pedestrians could be differentiated from other types of VRUs. A retrospective descriptive study, based on case records of VRUs fatalities from 2005 to 2012 referred to a tertiary care unit for post-mortem examination, was conducted. A pro-forma was developed to extract data from the post-mortem reports and toxicology reports. Data was analysed using SPSS version16. Out of the 328 cases 48% ($n = 157$) were pedestrians while 45% ($n = 147$) were riders/pillion riders of two wheeled vehicles and 5% ($n = 16$) were drivers/occupants of three-wheelers. The majority (87%) was males and 43% of pedestrians were elderly. 59% had 10–25 injuries and 87% had external injuries in the head, face and neck. The majority of skeletal injuries were in the skull followed by ribs. Analysis of different variables of pedestrians to other types of VRUs showed that the variables of, elderly male, road crosser, skull injuries, brain injuries, cause of death being head injuries and multiple injuries were significantly greater among pedestrian group (p: <0.001). The traffic hours (peak and off peak), number of injuries, rib injuries, limb injuries, crushed/run over injuries or lung and liver injuries had no significant association. Although some features helped in determining a pedestrian, many other factors were not associated to differentiate a pedestrian from other VRUs. Therefore, a forensic pathologist has to be cautious in expressing opinions when other corroborative evidence is lacking.

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1. Introduction

"Vulnerable Road User" is a term applied to those at more risk in traffic, i.e. those who are unprotected by an outside shield.[1,2] Therefore, pedestrians, pedal cyclists and motor cyclists have been considered as vulnerable since they benefit from little or no external protective device that would absorb energy during a collision. Although the category of vulnerable road user (VRU) may depend on the type of the vehicle used, categorization has to be considered depending on each country's situation. For an example, drivers and occupants of three-wheelers (tuk-tuks) have been considered as VRUs in 2009 WHO report since it is a popular mode of transport in low and middle income countries in Asia. On the other hand, a traveller who is on the foot-board or the roof top of an overcrowded public transport in Sri Lanka/India, a bullock cart rider, a rickshaw man and its occupant have to be categorized under vulnerable road users since they also don't receive any protection from a shield that would absorb energy during a collision.

World statistics on VRUs' deaths clearly show that, in low-income countries and some regions in Africa, Asia, the Caribbean and Latin America, the majority of road deaths are among pedestrians, passengers, cyclists, users of motorized two-wheelers and unsafe travellers of buses and minibuses.[3,4] The leading casualties in most high-income countries, on the other hand, are among the occupants of cars.[2] According to the statistics of the Sri Lankan Police, the number of road fatalities from 2004 to 2009 has been fluctuating around 2300-2500 deaths per year with the latest figure being **2721** deaths in 2011, showing an upward trend.[5,6] Although police statistics do not categorize VRUs separately, the percentage of pedestrian fatalities has been around 33% while drivers and riders amount to 44% and rest being passengers.

Road traffic fatalities are inquired by an Inquirer into Sudden Death or a Magistrate and undergo a post-mortem examination in Sri Lanka. A forensic pathologist who conducts such autopsy is not only expected to record injuries but also to give necessary medical opinion as to the cause and the circumstances of death. Thus,

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recognizing different patterns or locations of injuries in a VRU is very import to corroborate other evidence especially when the accident is due to rash and negligent act of an individual.

2. Objective

To study the injury patterns in different types of VRUs encountered in medico-legal autopsies and to find if pedestrians could be differentiated from other types of VRUs.

3. Study design

After obtaining ethical approval a retrospective descriptive study was carried out based on the case records of VRUs referred for post-mortem examination at a teaching unit of the North Colombo Teaching Hospital, Ragama, Sri Lanka (a tertiary care hospital in the Western Province) from 2005 January to 2012 December. A deceased vulnerable road user was defined as a pedestrian/motor cyclist (rider/pillion rider)/moped or scooter rider/pillion rider/cyclist/driver of a three-wheeler/occupant of a three wheeler/rider of a bullock cart or a traveller on the foot board of an overcrowded bus.

A pro-forma was developed to extract data from the case records. Post-mortem reports and toxicological reports were perused. Post-mortem reports where quality data cannot be extracted were excluded from the study. The pro-forma contained data on age, sex, type of vulnerable road user number of injuries, location of injuries, damage to the internal organs, as well as data on the cause of death and relevant opinions. Ethical clearance for the study was obtained from Ethics Review Committee of the Faculty of Medicine, University of Kelaniya, Sri Lanka.

4. Results

Analysis of the type of the VRU was based on the police information, eye witness records as well as final interpretation of the post-mortem report. During the study period of 2005 January to 2012 December a total of 7266 post-mortem examinations were conducted at the North Colombo Teaching Hospital where the study was conducted. Although 840 deaths of road traffic fatalities underwent post-mortem examination, only 504 deaths belonged to vulnerable road users group. However, 328 cases became eligible for the study considering the quality of the data. Among the study group 48% ($n = 157$) were pedestrians while 45% ($n = 147$) and 5% ($n = 16$) were riders/pillion riders of two wheeled vehicles (motor cycles and bicycles) and drivers/occupants of three-wheelers respectively. Unsafe travelling on the foot board or other modes of unsafe transport such as bullock carts accounted for 2% ($n = 8$) of the cases.

5. Age and sex distribution

87% of the study population were males where as male to female ratio was 6.3:1. The majority were over 40 years of age with 32% and 28% belonging to the age categories of 40–60 years and above 60 years respectively. In 12 (4%), person's age was not known. Young persons of 20–39 years comprised only 29% of the study population. The analysis of age group according to the type of VRU, revealed that the pedestrians consisted of more elderly men (>60 years) as opposed to others groups (Table 1).

6. Type of the alleged vehicle involved and the type of the activity, the VRU was engaged at the time of impact according to the history

A heavy vehicle was involved in the alleged incident in 43% (lorry/container: 25% and bus: 18%) of the cases, while in 27% of the cases a light vehicle (car/van) was involved. In 4% and 12% of cases the offending vehicle was a three wheeler and a two wheel vehicle (Motor cycle/bicycle) respectively. Other types of transportation (eg: Bullock cart) accounted for 7%, while in 4 cases multiple vehicles were involved. In 6% of cases information of the offending vehicle was not available. All "hit and run" incidents were categorized under this group.

The analysis of the type of activity VRU was engaged in according to the historical information resulted, 31% (n:103) as crossing and 35% (n:115) as riding/driving. 16% (n:53) of the VRUs were walking while 7% of the VRUs were turning or over taking. In 11% (n:37), the activity was not recorded.

7. External and internal injuries

We analysed the external injuries according to the body areas (Table 2) while bone injuries were categorized into main skeletal areas (Table 3) and visceral injuries according to their respective organs (Table 4). The injury distribution showed that although the percentage of external injuries were greater than the skeletal and visceral injuries in all VRUs there was no difference in the injury distribution pattern between the pedestrian and the other types of VRUs except skull and brain injuries. Out of 157 pedestrians, 109 (70%) had skull injuries but 119 (78%) sustained brain injuries. On the other hand out of 171 non-pedestrian VRUs, 11 (7%) and 25 (16%) had skull and brain injuries respectively (Tables 3 and 4).

8. Crushed/run-over injuries

28% ($n = 92$) of the victims had crushed/run over injuries and majority of them were seen in pedestrians (52 cases) as expected. However there was no statistical difference between the pedestrians and other VRUs (Table 5).

9. Cause of death

49% ($n = 159$) died from head injuries while multiple injuries were the cause of death in 35% ($n = 114$) of study population. Chest injuries abdominal injuries and spinal injuries accounted for 5% ($n = 15$), 3% ($n = 9$) and 3% ($n = 9$) respectively. 6% ($n = 20$) died of other causes such as Ischemic heart disease aggravated by minor trauma or other natural diseases like bronchopneumonia due to chronic debilitation following head or spinal cord injury.

10. Pedestrians VS other VRUs

The statistical analysis of different variables showed that being an elderly (>60 years) male pedestrian was statistically significant compared to other type of VRUs (Table 5). When considering the impact/collision, time of occurrence, the type of vehicle alleged to

Table 1
Distribution of VRUs according to age groups.

Type of VRUs	Age category							
	<10 years	11–19 years	20–39 years	40–60 years	>60 years	Not known	Total	
							n	%
Pedestrian	2	5	21	50	68	11	157	48
Two wheel	3	13	63	48	20	0	147	45
Three wheel	0	1	6	9	0	0	16	5
Unsafe travelling	0	0	3	0	2	0	5	2
Other	0	0	1	0	1	1	3	
Total	5	19	94	107	91	12	328	100
Percentage %	1	6	29	32	28	4		

Table 2
Distribution of external injuries.

Area of the body injured	Type of the VRUs		
	Pedestrians (157)	Other VRUs(171)	All VRU (328)
Head	141 (90%)	145 (85%)	286 (87%)
Anterior trunk	84 (54%)	104 (61%)	188 (57%)
Posterior trunk	72 (46%)	82 (48%)	154 (47%)
Upper limbs	114 (73%)	134 (78%)	248 (75%)
Lower limbs	112 (71%)	141 (83%)	253 (77%)

Table 3
Distribution of skeletal injuries.

Area of the skeleton injured	Type of the VRUs		
	Pedestrians (157)	Other VRUs (171)	All VRUs (328)
Skull	109 (70%)	11 (7%)	120 (37%)
Cervical spine	26 (17%)	32 (19%)	58 (18%)
Thoracic spine	15 (10%)	18 (11%)	33 (10%)
Lumbar spine	7 (4%)	6 (4%)	13 (4%)
Rib cage	98 (62%)	88 (51%)	186 (57%)
Pelvis	20 (13%)	21 (12%)	41 (13%)
UL	20 (13%)	21 (12%)	41 (13%)
LL	38 (24%)	36 (21%)	74 (23%)
No fracture	5 (3%)	8 (5%)	13 (4%)

be involved did not show any significant correlation between the two groups but a pedestrian crossing the road made that person more vulnerable compared to doing other activities.

Analysis of the injury pattern with regard to rib injuries, lower limb injuries, crush injuries, lung injuries, and liver injuries did not show any statistical difference between the two groups. However, analysis of the skull injuries and brain injuries showed a significant difference between the two groups indicating that head injuries are statistically significant in the pedestrian group compared to other VRUs. The same was seen in the cause of death where the combined figure of head injuries and multiple injuries became statistically significant in the pedestrian group compared to other VRUs (Table 5).

11. Discussion

Road traffic fatality trends are different in many parts of the world and majority of VRU deaths are reported from low income countries while vehicular deaths are common in high income countries.[2] Injury patterns of vehicular occupants differ from those of VRUs where head injuries are common in pedestrians and cyclists while chest injuries are common among vehicular occupants.[7] Many studies from the high income countries state that the majority of road traffic accidents lead to disability or death in adults, leading to a serious public health problem with high economic and social cost due to loss of earning.[8] Our study too, showed

Table 4
Distribution of visceral injuries.

Visceral organ injured	Type of the VRUs		
	Pedestrians (157)	Other VRUs (171)	All VRUs (328)
Brain	119 (78%)	25 (16%)	144 (44%)
Heart	29 (19%)	32 (19%)	61 (19%)
Lungs	62 (38%)	68 (40%)	130 (40%)
Aorta/major vessels	16 (10%)	15 (9%)	31 (9%)
Liver	39 (25%)	55 (34%)	94 (29%)
Spleen	20 (13%)	27 (17%)	47 (14%)
Kidney	14 (9%)	13 (8%)	27 (8%)
Intestines	11 (7%)	6 (4%)	17 (5%)
Pelvis	8 (5%)	9 (6%)	17 (5%)
No visceral injuries	10 (7%)	8 (5%)	18 (5%)

Table 5
Analysis of different variables in Pedestrians and other VRUs.

Variable	Pedestrians	Other VRUs	*P* value
<60 years	89	150	<0.001
>60 years	68	23	
Male	126	158	0.001
Female	31	13	
Traffic hours (peak hours)	81	94	0.534
Non traffic hours (off peak hours)	70	70	
Light and heavy vehicles	109	121	0.764
Other types of vehicles/no alleged vehicle	48	50	
Crossing	96	7	<0.001
Other type of activities	61	164	
Skull injuries present	109	11	<0.001
Skull injuries absent	48	160	
Rib cage injuries present	98	88	0.052
Rib cage injuries absent	59	83	
Lower limb skeletal injuries present	38	36	0.470
Lower limb skeletal injuries absent	119	135	
Crush/run over injuries present	52	40	0.057
Crush/run over injuries absent	105	131	
Brain injuries present	119	25	<0.001
Brain injuries absent	38	146	
Lung injuries present	62	68	0.995
Lung injuries absent	95	103	
Liver injuries present	39	55	0.162
Liver injuries absent	118	116	
COD given as head injuries or multiple injuries)	116	157	<0.001
COD other than head or multiple injuries	41	14	

similar trends where 61% of deaths were from 20 to 60 years of age group which constitutes the major working class and majority being males causing greater loss to the families, the male being the bread winner.

Studies from neighbouring countries such as India, Pakistan and Singapore showed similar road traffic fatality trends where two wheeler riders and pedestrians outnumbered the vehicular occupants with different mortality rates.[9–13] Elderly pedestrians have been reported in the medical literature to be more vulnerable to road traffic fatalities.[9–14] This trend has been observed in Sri Lanka as well. Our study too, showed similar trends to Bhalla et all in 2010[15] where elderly were commonly seen among road traffic fatalities compared to the young, unlike the autopsy based study in 80s where the most vulnerable group was young motor cyclists who died of head injuries.[16]

Analysis of the external injury patterns of VRUs showed that head and neck injuries being the commonest followed by lower limb injuries. It is a well-known fact that some types of injuries like de-gloving and imprint abrasions of tyre marks indicate run-over by a vehicle. Identifying a run-over injury is very important in event reconstruction, especially in 'hit and run accidents' since analysis of the injury pattern will help to identify the force and the type of the vehicle involved. In our study, although almost one third of the pedestrians had crush injuries indicating run over, there was no significant difference compared to the non-pedestrian groups. Thus it makes difficult to come to a conclusion that presence of a crush injury is necessarily a feature of being a pedestrian.

Differentiation of the injury pattern of a deceased pedestrian over other VRUs has become a forensically important factor to many Sri Lankan Forensic Pathologists with the increase in the number of accidents since the usage of vehicles such as motor cycles and three-wheelers have been on the rise in the recent past. Motor cycles have become the family vehicle of the lower middle class in many Asian countries where as three-wheelers introduced to Sri Lanka in 1990 to provide a convenient mode of public

transport to short distant urban areas[17] has become a necessary item in many city dwellers of middle and low income groups. A three-wheeler or a motor bike carrying 2-3 children together with one or two adults of the same family travelling short or long distance is not an uncommon sight in Sri Lanka. Therefore, we attempted to identify any significant difference between pedestrians to that of other VRUs (two/three wheel vehicles/other) using several variables.

The detailed analysis of the injuries in pedestrians versus non pedestrian (other) VRUs showed that the presence of skull and brain injuries being a significant variability while rib, lower limb, lung and liver injuries showed no significance. The other significant difference was seen in the cause of death where head injuries and multiple injuries were statistically significant among pedestrians compared to the non-pedestrian VRUs. This finding can be explained with biomechanics of pedestrian injuries as well as absence of protective gear such as helmets. Classically, pedestrian injuries consist of three phases: the bumper impact leading to lower limb injuries, windscreen impact causing chest and hip injuries and the ground impact leading to severe head injuries.[18] The vehicle impact velocity and vehicle front-end shape are other dominant factors that influence the pedestrian kinematics and injury severity.[19]

Motor cycle rider or the pillion rider though categorized as VRUs, due to the absence of a protective shield, mandatory requirement of wearing a helmet has reduced head injury mortality significantly around the world.[20,21] Mandatory helmet wearing for riders and pillion riders of motor cycles was introduced to Sri Lankan traffic legislation in early 80s. Hilmi et al. in 2010 reports high helmet usage by adults (97%) but low (31%) usage by children leading to increasing the risk of severe injury in Sri Lanka.[22] Although skull injuries and brain injuries in our non-pedestrian VRUs (mainly motor cyclists) were significantly lower compared to pedestrians, it was observed that the head injuries seen in motorcyclist fatalities are associated with not being adherent to proper procedure of wearing a helmet. This observation needs further studies.

This study was carried out at a tertiary care hospital with no neurosurgical facilities. Victims with head injuries brought to the hospital are transferred to National Hospital in Colombo. Therefore, relatively a large proportion of head injury victims who die later, after receiving neurosurgical care were not represented in this study. On the other hand, since the hospital is situated between two motorways, a large number of urban traffic accidents were represented in the study compared to semi-urban or rural area traffic accidents. The North Colombo Teaching Hospital being situated near the only rehabilitation hospital in Sri Lanka, also became a centre of choice of autopsy in chronic severely debilitated due to road traffic accidents after many months or years. Therefore, many delayed deaths were seen in this sample. Thus, generalisation of the results of this sample to represent Sri Lankan VRUs, island wide cannot be done.

Although the study showed that an elderly male (>60 years) with skull and brain injuries where the cause of death is either head or multiple injuries being a pedestrian has a high chance, using this as definitive opinion in forensic context has to be done very cautiously especially in hit and run accidents where corroborative evidence is lacking.

Ethical approval

Ethical approval was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Kelaniya, Sri Lanka.

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Contributions

Design to the study: PASE, IDGK, UDS Supervision to the study: PASE Analysis of the data: UDS, PASE.

Interpretation of the results: PASE, IDGK.

Writing and revising the manuscript: PASE, IDGK, UDS.

Conflict of interests

None.

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